

XXV.—*On some Objections to the Theory of attributing the Natural Terraces on the Eildon Hills to the action of water.*

By J. E. BOWMAN, F.L.S. & F.G.S.

MY attention having been directed, during the late meeting of the British Association at Glasgow, to an account of a series of very interesting natural Terraces on the hills round Galashiels in Selkirkshire, in a late Number of Chambers's Edinburgh Journal*, I took the opportunity of returning through that district to ascertain, by personal inspection, how far they agreed with the description. As my time was limited, I did not attempt a detailed examination, and was unprovided with any instruments for verifying the relative heights and levels of the terraces, so circumstantially given in the above article. As that valuable publication is in every one's hands, I shall at once refer to the article in question, merely saying, that my own observations will be much better understood if the reader will previously consult it; that the number of the terraces is sixteen, and that they run along the sides of many of the hills round Galashiels, Melrose, Abbotsford, &c., in perfectly horizontal lines, and parallel to each other; and are, in the opinion of their discoverer, so many different ancient beaches or land-levels, at which the sea must successively have stood for long periods. The staple of the article is from Mr. Kemp's own notes; and I am satisfied, from the opinion I formed of his ability, geological knowledge, love of truth and unpretending diffidence, that full reliance may be placed upon what he has so carefully and perseveringly worked out. I regret that I could not altogether agree with his conclusions; and I offer the following observations with considerable diffidence, because I had only a single opportunity, and that a hurried one, of seeing a small part of the appearances he has so repeatedly and attentively studied. Having seen the Parallel Roads of Glen Roy some years ago, I was naturally led, from the description of these terraces, to expect something of the same appearance and character; though a moment's reflection would have convinced me, that had this been the case, they would long ago have attracted general notice, and could not have escaped the searching eye of Sir Walter Scott, from whose windows at Abbotsford, the Eildon hills, on which some of the clearest examples occur, form a prominent feature of the scenery †. The fact is, that neither when viewed

* No. 444, for 1st August, 1840.

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from a distant point, nor when standing upon or near them, do they anywhere exhibit to the eye the continuity, the parallelism, or the perfect horizontality, either of level or of surface, so strikingly displayed in those of Glen Roy. Indeed, they are for the most part so broken and interrupted, and the detached portions often so obviously deflected from the horizontal plane, notwithstanding a general parallelism, that it is difficult to conceive them to have been formed by water. I think that most geologists would pass through the district, and even walk over them, without being aware of anything peculiar, unless their attention were specially directed towards them. This obscurity naturally led me to a more close examination of the limited portions I had the opportunity of visiting; and as some of the appearances did not strike me as being the result of tidal action, I have thought that in the present state of our knowledge of them, the cause of truth might be advanced by directing the attention of geologists towards those points which seem to be still obscure, notwithstanding the conclusion at which we must arrive from the general coincidence of the levels across intervening valleys.

I first ascended the northern flank of the Eildon hills from the valley of the Tweed at Melrose, passing from the old red sandstone, which forms the general surface of the district, to the greywacke, and from it again to the red compact felspar, which has burst through both, and forms the greater portion

writings of Sir W. Scott, are surpassed by none, to ask if he could point out any passage showing that he was aware of the existence of these terraces. I quote a portion of his reply:—"I believe I can answer you with positive certainty, and, as you say, 'at once,' (for my memory, as honest Parson Evans says, was always pretty 'sprag,') that though he very frequently, up and down, makes particular and fond mention of the Eildon hills, and places about Melrose, I am very sure he never notices any particular geological formation in those mountains, or surely it would have struck me, especially when similar to the Parallel Roads of Glen Roy, which I viewed with such intense interest in your society. In the 'Monastery' he gives a very minute and beautiful description, at some length, of a narrow valley above Melrose, there called Kennaquhair, down which a small river falls into the Tweed; but not one word of stone-ology, or any part of natural history, in which poets in general are miserably ignorant. From this censure, I must, however, except our matchless Shakspeare, and old father Chaucer," &c. &c.

Had Sir W. Scott been aware of these terraces, he would surely have interwoven some notice of them with the story of Mary Avenel. How much to be regretted that his fine spirit should have passed away in ignorance of the most interesting natural feature of a district he has so well immortalized! But "*non omnes omnia possumus*;" and to use his own nervous language in another place, "they have a' their different turns, and some can clink verses,—and some rin up hill and down dale, knapping the chucky stanes to pieces wi' hammers, like sae mony roadmakers run daft,—they say it is to see how the warld was made!"

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of the whole group. The eastern hill is for the most part covered with sward to the summit; so is the lower half of the middle one, the upper portion being nearly all naked rock. On the ascent to the uneven plain, or shoulder that connects the eastern with the middle hill, above mid-height, I perceived two or three of the terraces* upon the face of a great spur that shoots out from the latter above the beautiful ruin of Melrose Abbey. They seemed to range at about equal distances from each other, and to be from 80 to 100 yards wide; the upper being about three-fourths of a mile long, and nearly of equal width throughout. As I successively reached the level of each, I found the surface to be covered with vegetation, and to be far too uneven to have been formed or modelled by water. On attaining the plain or connecting shoulder just alluded to (which I took to be No. 10 of Mr. Kemp's series), I found the same inequality of surface, and also an evident general slope, not outwards from the hill towards the valley, but at right angles to that direction, and from a horizontal line that would have formed the beach when the water stood at that level.

On ascending the eastern hill the terraces between it and the middle hill were so obscure and broken up, and the intermediate slopes so irregular, that I could not trace them for any distance, or even in some places satisfy myself that they existed at all. It appeared (admitting they had once been there) that portions of them had subsequently slipped down, dividing horizontally into two or three, and then had rested in irregular and slanting positions on the intermediate spaces. The average slope of the hill here was 30 to 35 degrees, and the average deviation of the surfaces of these detached portions from the horizontal line, about 5 degrees; but this deviation was sometimes in one direction and sometimes in another; so that supposing a person were to walk along them, he would sometimes ascend, and sometimes descend. The diameter of the surface was also uneven, generally sloping outwards, but in one place inwards, the width being various, mostly from ten to twenty yards. In no one spot is the surface horizontal; yet, at the same time, it is necessary to say that, viewing them as a whole, they seem too uniform and regular to be accidental slips of detritus from above, and at first sight appear more like the remains of rude earthen entrenchments than the effect of any great natural cause. It

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would not affect the general truth of the formation of terraces by tidal action, to find occasional and slight inequalities of level; even if originally horizontal, such inequalities might be easily produced in the process of upheaving; and the real ground of surprise is that they should retain the uniform and perfect parallelism they do, as those of Glen Roy. But the deflections and discrepancies I now speak of are relative to the general surface of the terraces, and to each other, on the detached portions where they occur; and therefore, admitting them to have been sea-beaches, they must be occasioned by slips from increase of gravity of the mass, when raised out of the water.

On reaching the summit of the hill, the terrace No. 1 seems best developed on the S.S.E. side, and is extended into an irregular shaped plateau, whose surface, though approaching to a rude horizontality, is far too rounded and uneven to have been formed by the action of water. In one place, where the terrace can scarcely be traced, and where the deficiency might be attributed to a subsequent slip, there is no apparent accumulation below; but, on the contrary, a hollow or depression in the surface. On looking downwards on the S.E. side of the hill, I could see no other terrace below it.

The upper terraces of the middle hill may be comprehended in the above general description; their surfaces have many elevations and depressions, and for the most part slope outwards from the mountain. On both the hills, all that I examined consist of the same material, viz. a mass of angular fragments of the red compact felspar rock from above, the only difference being, that on the eastern hill they are mixed with a stiff red clay and covered with vegetable sward, while the upper ones of the middle hill have no such covering. I looked carefully on both, wherever I had the opportunity, for rounded pebbles, gravel, sand, or other drift, but without seeing a vestige of either. In the sequel I shall again allude to this peculiarity.

Looking back upon the group of the Eildons from the road between Melrose and Abbotsford, and all the way to Galashiels, several of the terraces on their northern face, which rises above Melrose and the broad valley of the Tweed, may be seen stretching in true horizontal lines of considerable length, the minor inequalities of level being lost in the general effect. This is an important fact in favour of their origin from water. I looked in vain for similar appearances on the opposite or north bank of the Tweed, on Cowden Knows, and up the valley of the Leader, in all which places the hills are lower and smoother, and for the most part covered with

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diluvium containing angular fragments of greywacke and trap rocks.

In the afternoon, Mr. Kemp kindly accompanied me on a hasty visit from Galashiels to Williamlaw. My time being limited and the evening advancing, he selected this hill as offering the best example of the terraces in the neighbourhood, for he had traced, more or less distinctly, detached portions of no less than eight of the whole series, between the summit and the base. Two or three of the lowest of these (7, 8, and 9 of his series,) are the broadest and most continuous, averaging 100, 120, and 130 feet wide respectively about the middle, where they appear to be swollen out, narrowing irregularly on each side till they are lost in the general slope of the hill. These occur on the south side of the hill, and front the valley of the Gala. On one of them the surface is raised in the middle or widest part, and declines each way towards the narrower extremities at an angle of 3 to 6 degrees, a vertical longitudinal section having this form:—



At first sight it appeared that both the greater width and the raised surface of the middle portion, might be caused by an accumulation of detritus from above; but on examination it was composed of the solid rock. On another, the central accumulation is so situated under a projecting rock, that it could not have found a lodgement there in falling from above; nor was there any trace of a furrow or ancient water-course which might have brought down diluvium, when this spot marked the level of the water. The natural slope of the hill in the neighbourhood of these lower terraces, forms an angle varying from 30 to 40 degrees.

A little to the westward of these, and higher up the hill, the series of inclined projecting ridges of hard greywacke rock, which are named in the article referred to as apparently contradictory, but are really confirmatory of the theory advanced, may be seen to greater advantage than either nearer the summit or the base. Regarding these, or rather the protuberances and intermediate indentations by which they are stated to be marked, as the *experimentum crucis* of the whole theory, I was anxious to satisfy myself of the coincidence of level between these points and the horizontal terraces; but after the best attention I was able to give, I regret to say, that whether from the unfavourable point from which I viewed them, with regard to perspective, or from the general ruggedness of the

diluvium containing angular fragments of greywacke and trap rocks.

In the afternoon, Mr. Kemp kindly accompanied me on a hasty visit from Galashiels to Williamlaw. My time being limited and the evening advancing, he selected this hill as offering the best example of the terraces in the neighbourhood, for he had traced, more or less distinctly, detached portions of no less than eight of the whole series, between the summit and the base. Two or three of the lowest of these (7, 8, and 9 of his series,) are the broadest and most continuous, averaging 100, 120, and 130 feet wide respectively about the middle, where they appear to be swollen out, narrowing irregularly on each side till they are lost in the general slope of the hill. These occur on the south side of the hill, and front the valley of the Gala. On one of them the surface is raised in the middle or widest part, and declines each way towards the narrower extremities at an angle of 3 to 6 degrees, a vertical longitudinal section having this form:—



At first sight it appeared that both the greater width and the raised surface of the middle portion, might be caused by an accumulation of detritus from above; but on examination it was composed of the solid rock. On another, the central accumulation is so situated under a projecting rock, that it could not have found a lodgement there in falling from above; nor was there any trace of a furrow or ancient water-course which might have brought down diluvium, when this spot marked the level of the water. The natural slope of the hill in the neighbourhood of these lower terraces, forms an angle varying from 30 to 40 degrees.

A little to the westward of these, and higher up the hill, the series of inclined projecting ridges of hard greywacke rock, which are named in the article referred to as apparently contradictory, but are really confirmatory of the theory advanced, may be seen to greater advantage than either nearer the summit or the base. Regarding these, or rather the protuberances and intermediate indentations by which they are stated to be marked, as the *experimentum crucis* of the whole theory, I was anxious to satisfy myself of the coincidence of level between these points and the horizontal terraces; but after the best attention I was able to give, I regret to say, that whether from the unfavourable point from which I viewed them, with regard to perspective, or from the general ruggedness of the

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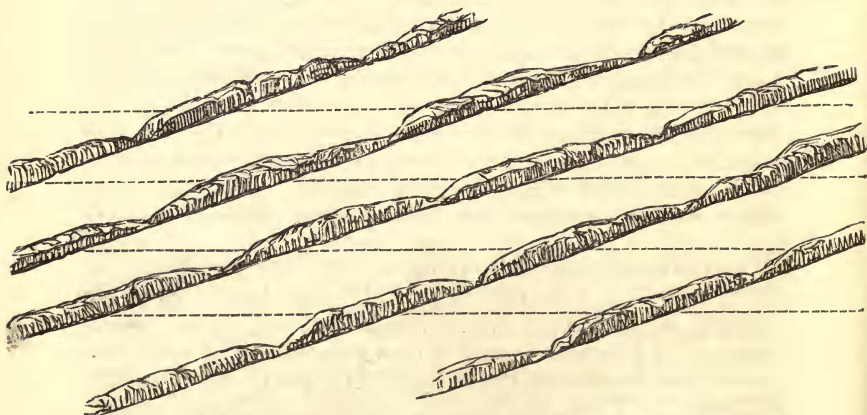
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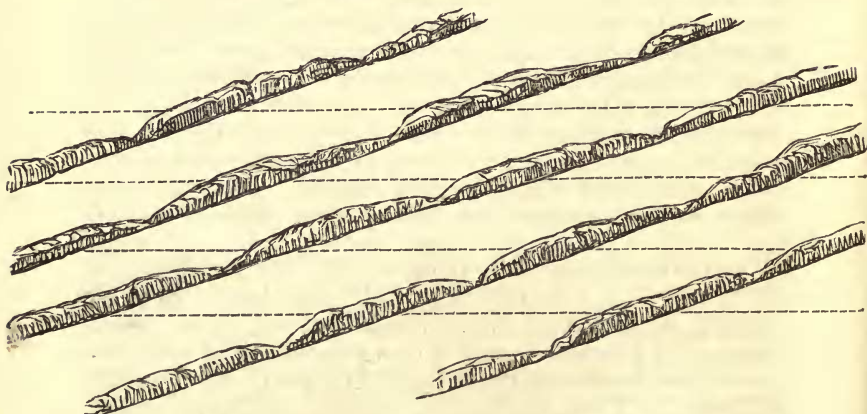
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outlines, and unaided by any instrument, my eye failed to recognize the points of intersection. The ridges themselves follow the slope of the hill to the west, and have an apparent dip of about six or eight degrees; but as the true dip of the beds composing them averages from 50 to 60 N.N.W., it is evident that their superficial outline has been determined by the slope of the hill, which intersects the beds diagonally and exposes their basset edges. In some parts they are very rugged and uneven, and project considerably above the general face of the hill; while the intervening spaces, which are so many sunken furrows, have a smooth covering of diluvium and sward, and an uniform and gradual slope corresponding with that of the ridges. As it is not easy by description alone to convey a correct idea of their combined form and character, I have constructed the following diagram of the appearance they should exhibit in perspective, according to the theory; but it shows them much more regular and uniform than they exist in nature, and marks the protuberances which Mr. Kemp says "range horizontally across them, and correspond in their respective levels with the terraces on the neighbouring hills." The shaded diagonal rows are the sloping ridges which rise out of the hollows, their curved tops showing the protuberances, and the dotted horizontal lines mark the supposed levels of the terraces; which, however, it must be remarked, do not appear here, but at corresponding heights in other places, and are only introduced to show the horizontal strike of the protuberances and intermediate indentations. This arrangement, as I have already observed, I failed to re-



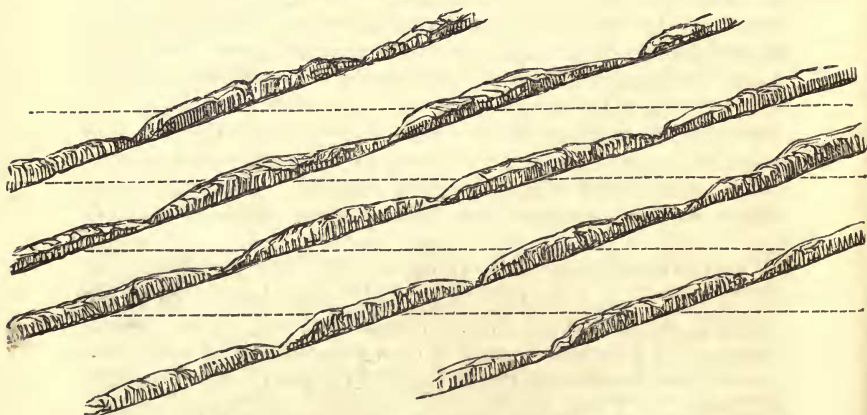
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support the opinion of their having been caused by the action of water, unless corroborated by being at corresponding levels with the terraces. I assume, however, on Mr. Kemp's authority, that such is the case. But as the terraces are believed to have been formed by tidal action, that cause, if it produced any effect at all upon the hard greywacke ridges, must have cut away those parts which appear as *indentations* (see the diagram), and which must therefore be considered as successively the actual lines of beach; whereas Mr. Kemp states, "that the *protuberances* correspond in their respective levels with the terraces on the neighbouring hills." Again, the broad inclined slopes between the elevated ridges, are covered with green sward, and form inclined planes with pretty uniform surfaces. Though I could nowhere cut through the sward to the rock below, I think it probable that these inclined hollows do "indicate the situation of softer intermediate beds which the action of the sea has washed away, leaving the harder beds comparatively bold and prominent*." But here another difficulty meets us: if the tidal action was sufficient to produce so marked an effect upon the projecting hard greywacke ridges, the softer intermediate beds must have been washed away to a much greater extent than they have been, and would have shown greater inequalities of surface; whereas they are generally smooth and uniform, and but a few feet below the ridges.

Again, wherever, either on the terraces or the intermediate slopes, fragments of the rock were exposed, they were angular and rough, with sharp edges, and did not show the least appearance of having been rounded or acted on by water. I could not find on Williamlaw, or on either of the Eildons, a single pebble, or gravel, or sand of any kind, indicative of the former presence of water. All were sharp angular pieces of the same rock as that of the hills respectively, to the exclusion of all foreign material. Now, if the water remained long enough at any single level to have left manifest and permanent indentations upon the hard ridges, it must have had ample time to convert the loose angular fragments which

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would be ground against each other by every tide, into smooth pebbles and shingle. Nor is it easy to conceive how terraces of 100 or 120 yards broad, as on the Eildons, formed of angular stones detached and precipitated from above, could have been made to assume by the action of water, even the irregular horizontality they do actually possess, when falling upon a slope having an angle of thirty or forty degrees; and this, without the stones showing any marks of attrition. On a gently inclined beach, where the tidal wave is ever and anon rolling such fragments over a considerable area, they would soon be converted into rounded pebbles; but on a steep rocky shore they would fall at once into deep water and assume the shape of a conical talus or "scree," where the tide would have comparatively little effect upon them. Their rough angular surfaces would lock into each other, and prevent them from being scattered over so broad a space as we see them on the Middle Eildon. It must also be borne in mind, in reference to the terraces on the eastern hill, which appear to have slipped down from their original situation, that the probability of their having done so is much weakened by their being composed of angular stones.

It struck me as singular, that all the terraces I examined, should be found on the sides of the respective hills most exposed to the strong currents that may be assumed to have been then in action; those on the north side of the Eildons, facing the great valley of the Tweed; those on Williamlaw, overhanging the more circuitous one of Gala water. Of course I conclude they do exist on the retired sides of some of the hills. One should have supposed, *à priori*, that the currents would have swept away the fragments of rock as they fell from above, and would have prevented them from accumulating into projecting shelves. Indeed, several of the best developed are *widest* precisely at the point where they project into the valley, and would come in contact with the current. I was also surprised to find no trace of terraces in other situations, apparently more favourable to their production. Immediately to the west of Williamlaw, and seen to advantage from its summit, is a wide and deep circular amphitheatre, formed by the smooth grassy sides of several neighbouring hills which environ it with very uniform slopes, except on the side that connects it with the valley of the Gala water. If the sea ever occupied the latter, it must also have filled this hollow, and converted it into a spacious, though sheltered and tranquil bay, round whose encircling sides, well-developed terraces might be expected to be found. Their total absence, therefore, from so favourable a locality, leaves room to inquire whether those which occur in more equi-

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vocal situations do really indicate the lines of ancient beaches.

On the north or highest of the two points of Williamlaw, and near the summit, are two broad indistinct terraces, whose surfaces slope considerably towards the southern or lowest point, and also to the west. The crest between the two points is a succession of low eminences and intermediate furrows, which have no connexion with any of the terraces, but are formed of the basset edges of the harder beds. As the dip and strike of these correspond in the main with those of the slanting ridges below, and as they are separated by similar smooth grassy hollows, there can be no doubt but the cause assigned by Mr. Kemp for the latter, is the true one.

At the south foot of Williamlaw, on the opposite bank of the Gala, is a broad level grassy plain, formed of diluvium at the time the whole valley was under water, and subsequently cut through by the existing stream. It reminded me strongly of the true terraces near the head of Glen Roy.

Having now stated, as clearly as I can, the observations that occurred to me on a hasty view of these terraces, I have only to express a hope that more competent geologists may be induced to examine them in greater detail. Whether the theory proposed by Mr. Kemp be the true one or not, the merit of having first discovered, and then worked them out with such ability and perseverance, will ever be his own. No one will rejoice more than myself to see my objections answered, and a cause assigned that shall explain the difficulties and harmonize with all existing appearances. Nor is this all; the complete explanation of any set of natural phænomena, lessens the difficulty of comprehending others, still obscure, to which they are allied; and is another step in advance towards the future solution of the grand problem, the aggregate causes that have produced the existing state of things upon our globe.

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Manchester, October 10, 1840.

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